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THE INITIAL PHASE OF A TROPICAL CYCLONE FROM "SOYUZ-9" SPACECRAFT PICTURES

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16. Abstract

The crew members of the spacecraft "Soyuz-9", A. G. Nikolayev and V. I. Sevast'yanov, took, over the tropical latitudes of the Atlantic Ocean, pictures of a convective cloud cell of a higher order than a simple cumulus. This cell is regarded by the authors of the article as being the initial phase of a tropical cyclone. However, unfavorable temperature conditions led to the breakdown of the convective cell, rather than to its transformation into a tropical storm.

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THE INITIAL PHASE OF A TROPICAL CYCLONE FROM "SOYUZ-9" SPACECRAFT PICTURES

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During the flights of the "Soyuz" spacecraft, as is well known, a program of special meteorological observations was carried out [3,4,6]. The purpose of the program was to accumulate materials concerning the less well known synoptic situations and the details of objects such as the fronts and central parts of cyclones [2], etc. Details of this sort cannot be discovered either from the Earth, on account of the observer's limited field of vision, or from a meteorological satellite, on account of the low resolution of the equipment.

A cosmonaut who is a meteorologist or one who is trained for meteorological observations possesses different possibilities in this respect. An observer in space can be warned in advance from a meteorological center on Earth about those areas where interesting situations are to be expected, so that he can prepare in advance for selecting and photographing the mesostructures. On the other hand, tracing the changes in the situation along the orbit, he, himself, can also choose the area where interesting objects are

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awaiting him. All of this creates broad possibilities for productive work of the observer on board a spacecraft.

During the flight of the piloted spacecraft "Soyuz-9", cosmonauts A. G. Nikolayev and V. I. Sevast'yanov observed and photographed various cloud forms characteristic for different cloud situations [4]. Let us analyze one of these pictures, obtained on June 15, 1970 in the tropics of the southern hemisphere over the Atlantic Ocean. The synoptic situation observed here on that day was quite a usual one for June; that is, a subtropical anticyclone with its ridge towards the Gulf of Gunea maintained a southeast trade wind in this part of the Atlantic.

In Photograph 7 is given a montage of two television pictures from the satellite "ESSA-9" on June 15 at 15:00 hours, 26 minutes, 40 seconds and at 15:00 hours, 31 minutes 00 seconds, Greenwich mean time. The zone of intratropical convergence had few large /52 cloud accumulations and, for this reason, was expressed unclearly in the pictures. However, its equatorial boundary can still be seen beginning from the Equator in the eastern part of the montage and extending to 5° north latitude in the western part, where there is a solid cloud accumulation. A northeast trade wind can be traced clearly in the direction of the low cloud banks. In the immediate vicinity of the Equator, there is an extensive zone which is almost cloudless, and farther south the cloud fields have the external appearance which is characteristic for the trade wind zone of this part of the Atlantic. That is, there are closed cells of solid stratocumulus clouds in the zone adjoining the cold waters of the Bengal current, while there are fine areas of open cells over the warmer waters in the central and western part [9].

Cloud accumulations which are more vivid and, therefore, more highly developed in the vertical direction are observed west of 15° west longitude and between 5° and 15° south latitude. Among the various cloud accumulations, when they are examined in greater dêtail, one's attention is drawn to the cloud accumulation which is bordered by the square in Photograph 7. This cloud accumulation is in no way notable at first glance. Somehow the accumulation I in its shape is reminiscent of a starfish with a more solid center and with offshoots going out on the sides from the center. On the south, in the corner of the square, there is a cloud bank II which adjoins this accumulation across a small cloudless interval. It ought to be noted that such a cloud accumulation was not here a few days before.

This cloud accumulation was photographed by the crew of "Soyuz-9" from an altitude of 221 kilometers on June 15, 1970 at 14:20 hours Greenwich mean time [1], that is, approximately one hour before the satellite photographs. In the close-up photograph (Photograph 8), it is now little reminiscent of a star, although, if one were to look carefully and to distinguish the drawn out, white condensed parts, they would form the same offshoots which in Photograph 7 give the cloud accumulation the shape of a starfish. In the photograph taken from the spacecraft, these white offshoots are masked by the bright shroud of the upper clouds and the fine banks of the lower clouds, which were not captured by the television equipment in Photograph 7.

When we carefully examine the cloud accumulation in Photograph 8, we observe that its northern part consists of more solid clouds of curling, cumulus shapes. One receives the impression that it is precisely here that the basic convective ascent of the air takes place. The light foggy shroud of cirrus clouds covering the curling tops extends towards the south, the southwest, and the southeast. This can be seen especially clear in the stereoscope

with the two adjacent photographs, which were obtained from the spacecraft after a short time interval (four seconds).

The cloud "cover", moving out in a fan shape, has noticeable streaks aimed from the nucleus of the accumulation out towards its edges. However, on the edges of the cloud accumulation, the shroud of cirrus clouds is sharply interrupted. This can be seen especially clear on the southern and southwestern outskirts.

Such a structure of the cloud cover compels us to conclude that the accumulation is a large, active convective cell of a higher order than a simple cumulus. The basic ascent of the air takes place in the northern part in an area of approximately 10,000 km^2. However, on the periphery of the entire immense convective cell (the cloud formation has a diameter of 200 km), the descending movements carry the wind downward, the clouds are washed away, and the cloud edge acquires sharp outlines.

The vertical structure of the cloud accumulation described here may be reminiscent to a certain extent of the structure of the very thick convective cloud shown in the picture in Photograph 9. This picture was taken by A. G. Nikolayev and V. I. Sevast'yanov from the spacecraft "Soyuz-9" on June 13 during /53 the evening. The picture was taken from the side at an angle. In the right hand part, there is a tower of thick cumuli, the upper part of which spreads out to the left along the air stream to a great distance, approximately from the southwest to the northeast. The picture is really quite a unique one.

However, let us return to Photograph 8. Around the cloud accumulation in the upper and middle troposphere, there is formed a ring of cloudless space with a width of about 40 kilometers.

Behind it, to the south and southwest, we see the solid cloud bank which we already mentioned above. In the lowest layers of the troposphere, in the zone of the cloudless ring, we can see clearly cumuli of types Cu med and Cu cong. In many parts of the picture they form banks, the orientation of which corresponds to the orientation of the southeast trade wind. However, in those places (the lower right-hand corner of the picture) where the orientation of the trade wind generally coincides with the direction in which the air is drawn into the large convective cell in the lower layers, the banks are less sharply accentuated and the clouds in them are larger. On the contrary, behind the large convective cell (the left edge of the picture), the direction of the trade wind is opposite to the direction in which the air is drawn in, the banks are more weakly accentuated, and they are partly broken up into small convective cells of the open type, which are characteristic for weak winds. The induction of air into a convective cell in the middle troposphere may also be seen along solid and rather narrow curved strips in the western half of the cloud accumulation.

The cloud accumulation examined here, which amounts to a large convective cell, is highly reminiscent of the initial stage of a tropical cyclone. In its entire system of movement, there is not enough sharply accentuated revolution around the vertical axis. It is probable that, under some conditions which are as yet little known, such revolution does occur, and the cloud accumulation is transformed into a tropical cyclone.

There is a series of photographs of tropical hurricane Bernice over the Pacific Ocean. In the initial stage of its development, when the tropical storm was a weakly accentuated depression, in its external appearance it was very similar to the convective cell we are examining, although its dimensions were twice as large (photograph of July 9, 1969)[8]. Later on, it developed into a

tropical hurricane. In our case, such a development did not take place, and in the following days the convective cell could no longer be observed in the spacecraft data.

One may also refer to Technical Note No. 124 published by the WMO [10]. According to the classification of tropical and subtropical disturbances given there on the basis of spacecraft data, the earliest phase of development of a cyclone (stage A, Fig. IV.5.2) assumes the form of a solid amorphous mass of clouds composed of cumulus and cirrus forms, and also of stratified clouds of the middle layer in any combinations. In this stage, there is usually a spreading of the cirrus clouds in the different directions.

One of the reasons why the convective cell was broken up without developing further was, probably, the temperature conditions on the ocean surface. As is shown in the work of academician V. V. Shuleykin [7], and also in accordance with empirical data, tropical cyclones develop over ocean areas where the water surface has a temperature higher than 26° C. According to ship observation data, the water temperature at that time was 24 - 25° C in the waters of that part of the Atlantic where the cloud accumulation appeared. Generally speaking, it is always relatively cold here, since the cold waters of the Bengal current penetrate there, and tropical cyclones do not develop.

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